

Identifying Case Studies

- Internal EPA query to relevant Regional and state staff
- · Broad grey and white literature review
- Review of existing EPA and other guidance documents
- · Query of selected industry practitioners
- Supplemental search of Clean Water Needs Survey (CWNS) database

3

Case Study Selection Criteria

- · Responsiveness to project objectives
 - relatively basic (non-advanced) treatment plants
 - improved nitrogen and/or phosphorus reduction using low-cost techniques
- Availability of monitoring and cost data
- Representative of a range of scenarios and nutrient optimization approaches

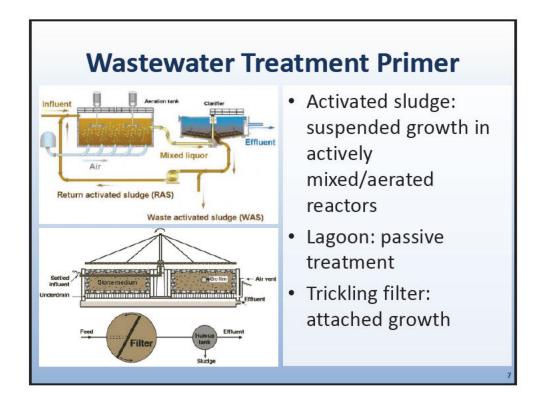
Case Study Selection

- From a master list of over 80 case studies, a total of 12 were summarized in report
- Of the 12 selected case studies, seven fully meet the main study criteria
- Other five provide useful information that might help target audiences understand nutrient reduction optimization approaches

5

Case Study Selection Findings

- Despite extensive efforts to identify and develop relevant case studies, few met the study criteria
- Most efforts at improving non-advanced plants appear to be unpublished or underdocumented
- Most published literature focuses instead on optimizing existing enhanced nutrient removal (ENR) systems



apital Costs Operational Costs/Savings
70,365 Savings not quantified
80,000 Zero
B1,000 Energy savings more than offset \$1,000/yr in maintenance
6,000 \$17,440/yr savings
10,000 \$1,000/yr
Zero Zero
53,000 \$13,500/yr savings
Zero \$34,000/yr savings
Zero \$519,900/yr savings
240,000 \$45,000/yr
100,000 10% savings
16,000 Savings not quantified

Optimization Approaches

- Aeration modifications are changes to physical aeration equipment, controls, operation, and function of equipment and aerated areas
- Process modifications include adjustments to process control characteristics
- Configuration modifications are changes to, or the addition of, flowstreams within the process or changes to the process configuration
- Chemical modifications are the addition of, or changes to supplemental alkalinity and organic carbon feed
- Discharge modifications are made at the end of the treatment system to further reduce nutrients prior to delivery to receiving surface waters

Optimization Modifications													
	Modification	Bay Point	Bozeman	Chinook	Crewe	Flagstaff	Hampden Township	Layton	Montrose	Tampa	Titusville	Victor Valley	Molfohoro
		٧	٧	٧		V	٧	٧				٧	
Aeration	Mixer addition			٧									
	Adjustable control aeration	٧	٧		٧		٧			٧		٧	,
	Equipment retrofit											٧	,
	Flow equalization improvement	V											
	Recycle rate control					٧							
Process	Side-stream control					٧			٧				
	Batch program modifications							٧					
	Predigestion of primary sludge					٧							
	Plug flow/series operation		٧				٧						
Configuration	Anoxic zone RAS bleed	٧								٧	٧		
	Anaerobic zone VFA addition										٧		
and section and the	Alkalinity feed improvements	٧			٧								
Chemical	Carbon product addition				٧								
(Soil dispersal											٧	
Discharge	Wetland discharge										٧		

Nitrogen Removal and Optimization

- WWT removal of nitrogen typically relies on natural biological processes
 - Cell uptake
 - BNR (biological nutrient removal): nitrification/denitrification
 - Anaerobic ammonia oxidation
- BNR is most feasible for optimization
 - Sequential oxic/anoxic conditions
 - Many ways to support/optimize the process



Phosphorus Removal and Optimization

- WWT removal of phosphorus is typically by sequestration in solids
 - Cell uptake
 - Enhanced Biological Phosphorus Removal (EBPR): increased cell uptake
 - Chemical precipitation/immobilization
- Chemical precipitation is most feasible for optimization
 - EBPR usually requires additional reactor(s)
 - Chemical treatment is easy, reliable and capable of low levels of effluent TP
 - Several drawbacks to chemical treatment

Typical WWTP Performance

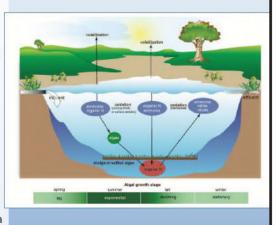
Treatment System	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)
Raw Wastewater	40	7.0
Primary Treatment	37	6.2
Activated Sludge (no ENR)	25	5.6
Facultative Lagoon	16	4.2
Trickling Filter	25	5.8

Sources: Metcalf and Eddy (1991, 2004); WEF (2003); USEPA (2011)

13

Lagoons

- Characteristics
 - Algae/wind aerate surface
 - Anoxic/anaerobic bottom layers
 - Relative long retention times
- Nitrogen removal mechanisms
 - Ammonia stripping to the atmosphere
 - Assimilation into biomass
 - Biological nitrification/denitrification
 - Sedimentation of insoluble organic nitrogen
- Phosphorus removal mechanisms
 - Physiochemical: adsorption, coagulation, and precipitation



Lagoon Optimization

- Controlled discharge
 - Coincide with times when effluent nutrient concentrations are lowest and/or when receiving water impacts will be lowest
 - Works well for non-discharge, since water demand is highest and receiving water sensitivity typically higher in summer
- Use non-discharge options, such as land application/soil treatment system
- · Consider adding post-lagoon treatment
 - relatively passive constructed wetland systems
 - post-denitrification facilities such as biological filters
- Documentation in literature is limited

15

Trickling Filters

- · Limited optimization options
 - Increase internal recycle rate
 - Aeration throttling/cycling for forced draft systems
 - Post-treatment or conversion to advanced secondary system
- Documentation in literature is limited

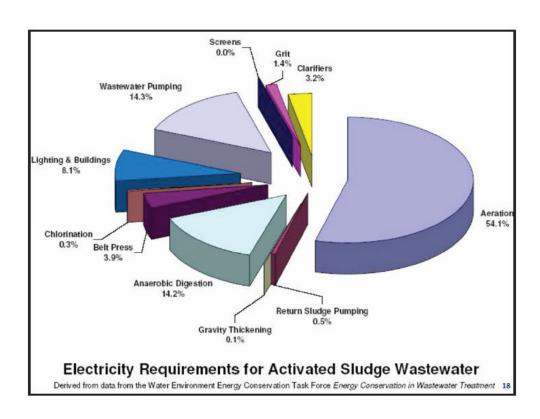
Author	Year	Location	TN	TP	Improvements
Dai et al.	2013	Australia	60%		Return nitrate-rich stream from secondary clarifiers back to primaries
Dorias and Baumann	1994	Germany	15 mg/l		Denitrification in trickling filter plants by covering filters for anoxic operation
Kardohely and McClintock	2001	Penn State			Added BNR plant to blend effluent prior to disposal or land application
Morgan et al.	1999	Australia			Conversion to MLE-type BNR by adding secondary reactors

ı

Activated Sludge

Aeration

- Aeration cycling includes on/off cycling of aeration, including the creation of dedicated anoxic and oxic zones, and associated controls.
- Adjustable control aeration use of variable frequency drives to control aerator output and/or use of on-line monitoring tools to inform aerator operational mode.
- Mixer addition addition of mixers to facilitate on/off cycling or maintain suspension of solids when aerators are turned down.
- Equipment retrofit replacement with more efficient aeration equipment.



Activated Sludge

Process

- Flow equalization improvement improving the influent flow to biological treatment process to improve performance consistency.
- Recycle rate control modifying internal mixed-liquor recycle rate to optimize denitrification in primary anoxic zones.
- Sidestream control modifying nutrient-rich internal plant return flows, such as sludge dewatering returns.
- Pre-digestion of primary sludge modifying primary sludge wasting rate to facilitate biochemical oxygen demand (BOD) solubilization from settled sludge into secondary process influent.
- · Batch program modifications changes to SBR program settings.

19

Activated Sludge

Configuration

- Plug flow/series operation conversion of complete mix reactor to plug flow to facilitate oxic/anoxic zonation.
- Anoxic zone bleed introduction of influent wastewater or return activated sludge (RAS) into anoxic reactors to provide carbon for denitrification.
- Anaerobic zone VFA addition introduction of RAS into anaerobic selector to provide carbon for enhanced biological phosphorus removal (EBPR).

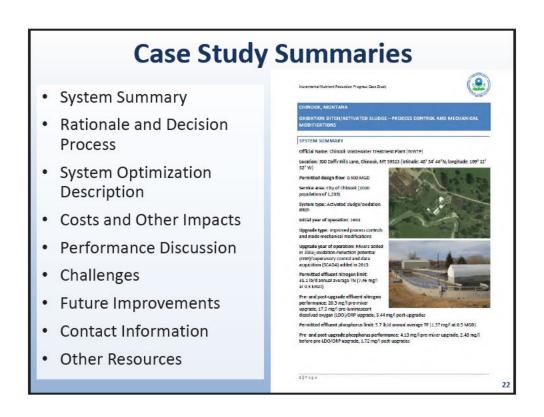
Chemical

- Alkalinity feed improvements modifications to alkalinity control systems to facilitate effective nitrification.
- Carbon product addition addition of soluble BOD products to enhance denitrification or EBPR.

Discharge

- Soil dispersal conversion of a surface discharging system into a soil discharging system.
- Wetland discharge discharge into wetlands for further attenuation of nutrients prior to receiving water delivery.

WWTP type	Key questions to ask	Optimization efforts to consider
Activated Sludge	Is there excess plant capacity? - Is peak daily flow < 75% design capacity? - Are additional tanks/reactors available? - Is flow equalization provided?	On/off cycling for nitrification/denitrification in single reactor Feed influent and internal recycle to dedicated tank Denitrify in flow equalization with internal recycle
	Is there excess aeration capacity? - Can aeration be throttled? - Does aeration system have automatic control? - Can contents be mixed without aerating? Are process parameters sufficient? - Can nitrified liquor be returned to low DO zone? - Is alkalinity sufficient for full nitrification? - Is carbon available to drive denitrification?	Modify process parameters as warranted - Internal recycle to introduce nitrified liquor to anoxic
Lagoon	Is capacity available to store effluent? Is the lagoon mechanically aerated? If so, can it be controlled (see Activated Sludge rows above)? Is a nondischarge alternative available?	Control discharge to take advantage of summer nutrient removal, while maintaining receiving water standards Create anoxic zones for enhanced BNR Study alternative discharge methods
Trickling Filter	Does trickling filter currently nitrify?	Add post-denitrification unit



Layton, FL

- Permitted design flow: 0.066 MGD, monthly average
- System type: Sequencing batch reactor (SBR)
- Upgrade type: Process control modifications
- Permitted effluent nitrogen limit: 12.5 mg/l, monthly average TN. 10 mg/l, annual average TN



Layton, FL

Changed SBR programming
— mix only for fill cycle
— cycle blowers on and off as needed
Real-time DO and ORP monitors

\$53,000 for probes
\$15,000 annual savings (energy, lab, sludge hauling)

Pre: 7.88 ± 4.26 mg/l
Post: 3.33 ± 1.87 mg/l

Chinook, MT

- Permitted design flow: 0.500 MGD
- System type: Activated sludge/oxidation ditch
- Initial year of operation: 1984
- Upgrade type: Improved process controls and mechanical modifications
- Permitted effluent nitrogen limit: 7.46 mg/l (at 0.5 MGD)
- Permitted effluent phosphorus limit: 1.37 mg/l (at 0.5 MGD)



Chinook, MT

- · Mixers added in 2004 to save energy
- Permit reissuance in 2012 required nitrogen removal
- Staff received MDEQ nutrient removal training and applied knowledge
- 2012 ORP probe and integration with SCADA = \$5,000
- 2004 (mixers, DO probe, SCADA) cost = \$68,200
- 2013 the DO probe was replaced with LDO = \$8,000
- Almost no annual costs. Energy cost savings.

Average Monthly Concentration	Pre-Mixer Upgrade	Post-Mixer Upgrade	Post-ORP/LDO Control Upgrade	Units
Effluent Total Nitrogen	20.3	17.3	5.44	mg/l
Effluent Total Phosphorus	4.13	2.48	1.72	mg/l



Crewe, VA

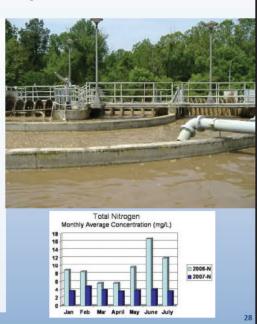
- Permitted flow: 0.5 MGD
- System type: Three-channel Orbal oxidation ditch activated sludge; phosphorus precipitation using alum
- Initial year of operation: 1956 (trickling filter plant) 1997 (oxidation ditch upgrade)
- Upgrade type: Process control modifications
- Upgrade year of operation: 2007
- Permitted effluent nitrogen limit: 6.0 mg/L (at 0.5 MGD)
- Permitted effluent TP: 0.5 mg/l



27

Crewe, VA

- 2007: New permit limits for TP and TP
- PER: \$500K-1M upgrade
- DO Control
 - Alter disc configuration
 - Manual On-Off cycling.
 - 24 hour programmable timer
 - On-line DO monitoring
- Reduce DO recycle to anoxic: RAS below water level
- · Molasses product for TN and TP
- Sidestream TN management: digester control
- · \$6K for DO control system
- · Approx. annual savings: \$26K



Victor Valley, CA

- Permitted design flow: 13.8 (originally 18) MGD
- System type: Conventional activated sludge
- Initial year of operation: 1981
- Upgrade type: Improved process controls and mechanical modifications
- Upgrade year of operation: 2007-2008 (additional upgrades in 2013)
- Permitted effluent nitrogen limit: 8.3 mg/l, TN, monthly average





Victor Valley, CA

- RWCB: 6.0 mg/l TN limit (revised to 8.3)
- Engineering report: New treatment train ~\$80M
- Recirc. Pumps for dedicated anoxic zone
- DO/ORP monitoring for simultaneous N/DN
- Operation at minimum sludge age
- \$1.1M capital costs
- ~10% operational cost savings



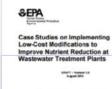
Conclusions and Recommendations

- Optimization is often feasible and cost-effective: need a "champion"
- Some excess treatment capacity is ideal (though we didn't specifically analyze this)
- Phosphorus removal is often complimentary to nitrogen removal
- Low-cost nutrient optimization is currently underreported
- Lagoon systems appear to have optimization opportunities
- Other approaches can also be considered on a case-bycase basis

31

Next Steps

- EPA released the draft report in August 2015.
 See: http://www2.epa.gov/nutrient-policy-data/reports-and-research#reports
- Seeking more data for an updated version, may collaborate with others who are interested in POTW optimization
 - EPA has already received several new case studies
 - Please submit comments or additional case studies to <u>POTWOptiNP@epa.gov</u> by December 15, 2015
- Exploring how to better align this work with efforts to improve POTW energy efficiency.
 - For example, EPA Region 4 now working with its states and communities to reduce POTW energy consumption and optimize nitrogen removals





Questions

Victor D'Amato 919-485-2070 victor.damato@tetratech.com